



Industrial Waste Management- I



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Hazardous Waste Management

Hazardous Waste Definitions and Laws
Hazardous Waste Management
Waste Hierarchy
 Reduce / Substitute
 Reuse
 Recycle / Recovery
Hazardous Waste Treatment
Wastewater Treatment
Case Study



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U.S. History of Hazardous Waste Pollution

- In 1962, renowned author and naturalist, Rachel Carson, warned growing contamination "great underground seas" (i.e., groundwater) in "Silent Spring."
- Love Canal – New York, USA. Buried barrels of chemicals underneath new housing development (1950s). Became main cause for the Superfund legislation. Removed from Superfund in 2004.
- Valley of the Drums – Kentucky, USA, 23 acre site with a large number of leaking drums. Fire at site in 1966. Not completely cleaned up until 1990.
- Times Beach – Missouri, USA community where contaminated oil was used for dust control from 1972-1975.



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Relevant U.S. Environmental Legislation and UN Convention

Primary U.S. Legislation

- Clean Air Act- 1970
- Clean Water Act – 1972
- Safe Drinking Water Act – 1972
- Resource Conservation and Recovery Act- 1976
- Comprehensive Environmental Response, Compensation and Liability Act of 1980 (**Superfund**)
- Hazardous and Solid Waste Amendments - 1984 (**Land Ban**)
- Pollution Prevention Act -1990



U.N. Convention

- Basel Convention 1992- Control of Transboundary Movements of Hazardous Wastes and their Disposal



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Definition of Waste

Definition of Wastes- Basel

"substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law"

Definition of Hazardous Wastes- EPA

"liquid, solid, contained gas, or sludge wastes that contain properties that are dangerous or potentially harmful to human health or the environment."

Characteristic – Ignitable-Corrosive-Reactive-Toxic
Listed – Industrial source-Type



Organisation for Economic Co-operation and Development (OECD) Definition of Waste

- Materials that are not prime products (i.e. products produced for the market) for which the generator has no further use for own purpose of production, transformation or consumption, and which he discards, or intends or is required to discard.
- Wastes may be generated during the extraction of raw materials during the processing of raw materials to intermediate and final products, during the consumption of final products, and during any other human activity.

The following are excluded:

- Residuals directly recycled or reused at the place of generation (i.e. establishment);
- Waste materials that are directly discharged into ambient water or air.



Surface and Groundwater Contamination Leads to Health Problems, Water Shortage

- Mining
 - Acid mine drainage
 - Heavy metals – Hg, Cr, Pb
- Industrial / Commercial Pollution
 - Dyes and pigments
 - Petroleum / gasoline
- Agricultural runoff
 - Pesticides
 - Nutrients – nitrates, phosphates
 - Salinization – Sodium, chloride
- Sewage
 - Pathogens - Enteric
 - Nutrients – Nitrates, phosphates
 - Contaminated animal feed



Textile Waste



Petroleum



Mining Waste



Drinking Water, Wastewater Contaminants Directly Affect Public Health

Pathogens

- Bacteria – Enteric, fecal
- Protists – Cysts and spores
- Virus - Enteric

Metals

- Copper
- Lead
- Arsenic

Disinfection byproducts

- Trihalomethanes - CHCl_3 , CH_2Cl_2 , CH_2ClBr
- Haloacetic acid – $\text{CH}_2\text{ClCO}_2\text{H}$
- NDMA

Pesticides





Solid Waste can Directly Impact Human Health

Solvents

Gasoline, diesel, chlorinated

Leachates

Acid waste, heavy metals

Hazardous waste

Metals, paints, solvents, pesticides

Leaking fuel tanks

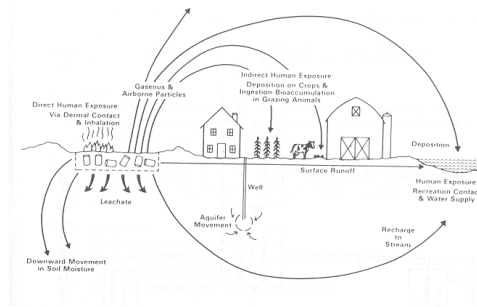
Gasoline, diesel

Refuse

Decaying animal and plant matter



Various Pathways Exist for Contamination From Land Disposal

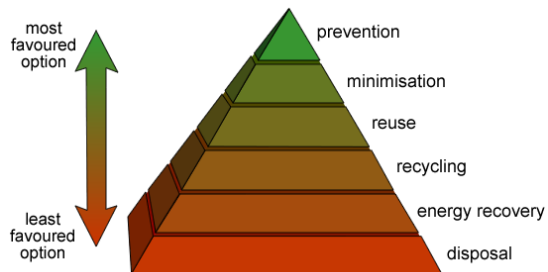


Effective Waste Management Program Involve Planning

1. Define Current Industrial Waste Management Practices.
2. Identify Industrial Waste Management Improvement Options.
3. Compile Findings / Assessment Report.
4. Evaluate Industrial Waste Program Scenarios.
5. Select Preferred Industrial Waste Program.
6. Start the Selected Program.



Solid Waste Hierarchy: Reduce, Reuse, Recycle, Treat and Dispose



Source: http://en.wikipedia.org/wiki/Waste_hierarchy



Industrial Hazardous Waste Reduction

- Reduce the amount of reactants necessary
- Incorporate green chemistry
 - 12 principles-reduce energy, catalysis, reduce derivatives, design to decompose....
- Improve recovery of product
- Reuse/recycle off-specification product
- Separate waste streams (cooling water, storm water, process water)
- Combine streams for neutralization



Industrial Hazardous Waste Reduction

- Improve process control
- Improved equipment design
- Use of different raw material
- Good housekeeping
- Preventive maintenance
- Industrial ecology
 - Colocate plants
 - Waste exchange program
 - Waste heat as a resource
 - Beneficial use
 - Waste to energy



Substitution of Hazardous Materials

Substitution of hazardous substances is an innovation process

- Uncertainty of success
- Inertia
- Economic risk assumed to lower ultimate risk

Straightforward systems

Cement
Mineral fibers
Substitution and maintain technical effectiveness

Complex systems

Textile auxiliary agents
Supply chain globally interlinked, more complex products



Metals Recycling –Resource Recovery and Landfill Protection

Steel
Aluminum
Mercury recycling
Batteries
Lead
Battery Acid
Cadmium
E-Waste



Off –Specification Materials Returned to Process



Industrial Byproducts can be Recycled

Construction and Demolition Wastes
Fly Ash, Bottom Ash, Slags
Flue Gas Desulfurization Gypsum
Phosphogypsum
Red Mud
Tires



Source: Wikipedia - Harvey Hinklemann



Example: Waste Tires - Technology in Recycling

Simple

- Used to prevent erosion
- Artificial reefs
- Tire derived fuel- cement kiln
- Crushed to crumb rubber for asphalt
- Pyrolyzed to make oil
- Cryogenic grinding- specialty
- High recovery devulcanization



Complex

<http://www.youtube.com/watch?v=Vgk1UZ242dM>
<http://www.youtube.com/watch?v=xmOkvUjgTLQ>



Example: Spent Catalyst Recovery and Disposal for Petroleum Refineries

- Catalytic cracking- Zeolites regenerated in process
- Hydrotreating – Ni, Mo, W, Co recovery
 - Acid and caustic metals separation and precipitation. (Hydrometallurgical)
 - High temperature fusion (Pyrometallurgical)
- Naptha reforming - Pt or Re on silica or silica alumina support (Recycled for precious metal-chlorinated precipitate)
- Steam reforming - Ni oxide catalyst on alumina support (Nickel recovery Alumina + NaOH)



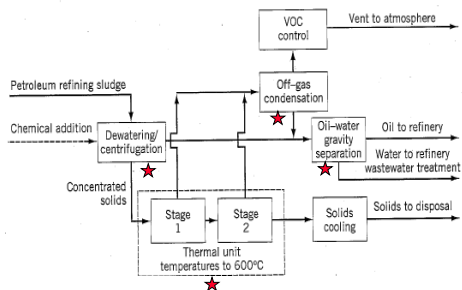
Source: www.matrostechn.com



Thermal Technologies for Oily Waste- Recycling Options

- **Separation - recycle**
 - Solvent Extraction
 - Centrifugation - Hydrocyclones
 - Air and Steam Stripping
 - Distillation
 - Recycle

Unit Operations for Product Recovery - Refinery Waste (Thermal Desorb)



Pretreatment of Petroleum Refinery / Oleo Waste

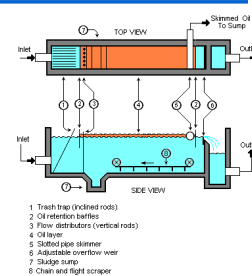
•Heating and decantation with gravity separation

•De-emulsifying
•Electrostatic coalescers
•Oil in water
•Water in oil

•Separation – Centrifugation- Filtration

•Solvent extraction

•Thermal distillation – Product recovery



API Gravity Separator

Source: Milton Beychok Wikipedia

Oily Water Extraction, Separation and Treatment Processes

Solvent Extraction

- Preparation (sorting the contaminated material)
 - Extraction
 - Separation of concentrated contaminants from solvent
 - Removal of residual solvent
 - Contaminant recovery, recycling, or further treatment.

Air or Steam Stripping

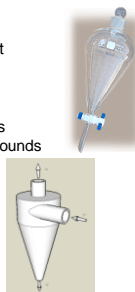
- Similar to distillation – recovery and recycle of organics
- Steam stripping can recover low VP and soluble compounds

Centrifugation

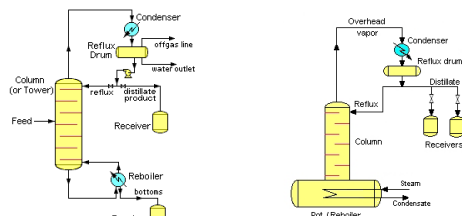
- Hydrocyclone: oil water separator
- Decanter: slop oil, 3 component sludge

Wet Air Oxidation

- Organic waste oxidation in water
- 150°C-325°C, 300psi-3000 psi



Distillation: Continuous and Batch



Source: J.T. Padleckas-Wikipedia



Distillation Pros and Cons

• Advantages

- Recovers useable organic solvents from wastes.
- Product purity of a range of levels can be designed into the distillation process, limited mainly by economic considerations.

• Disadvantages

- Costs of recovery often exceed cost of thermal destruction.
- Complex operation high capital cost, high energy costs.
- Columns can be large if a high degree of purity is required (200 feet).
- Feed must be a free flowing fluid with low solids content.
- Must be custom designed for a given waste stream not for variable feed.



Water Pollution Treatment Processes are Well Established

Water Pollutant	Treatment
Organic chemicals	Air stripping, distillation, oil water separators, adsorption
Biological oxygen demand (BOD)	Aerobic digestion, activated sludge-fixed film and suspended
Chemical oxygen demand (COD)	Aerobic digestion, activated sludge-fixed film and suspended advanced oxidation
Suspended solids (turbidity)	Settling, coagulation, filtration
Color	Coagulation, filtration, adsorption
Metals	Coagulation, filtration, ion exchange, membranes
Microbes	Activated sludge, disinfection
Dissolved solids	Distillation, membranes, electrodialysis, ion exchange



Wastewater Treatment

• Primary

- Screening
- Sedimentation / Flotation
- Hydrocycloning

• Secondary

- Activated sludge/ lagoons

• Tertiary

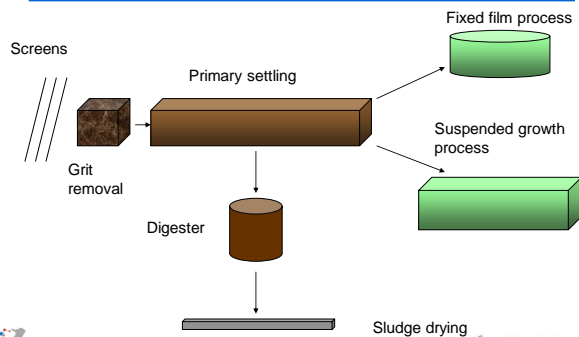
- Oxidation / adsorption

• Dewater sludge

• Digest or incinerate



Wastewater Treatment – Biological Processes



Wastewater-Fixed Film Biological Process



Trickling filter



Rotating biological contactor
(40% submerged rotates at 1-1.5 rpm)

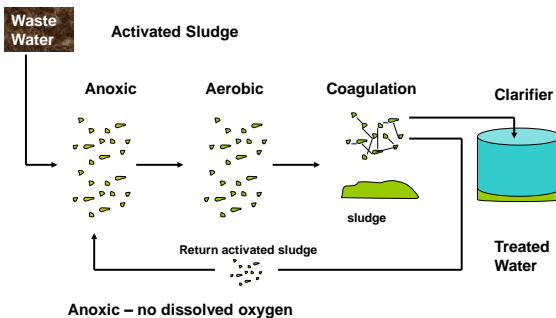
Uses biofilm to treat water to remove BOD

Suspended Growth (activated sludge) Process Requires Energy



- Use forced air suspension of biological sludge to reduce BOD
- Largest expense for this process is the electrical energy required

Wastewater Suspended Growth Biological Process



Wastewater Treatment- Generic

•**Coagulation / Flocculation** – removes suspended solids whenever natural subsidence rates are too slow to provide effective clarification

- Water clarification
- Lime softening
- Sludge thickening
- Dewatering

•**Solids / Liquid Separation**

- Sedimentation– gravitational settling
- Air/Gas Flotation
- Filtration
- Centrifugation



Wastewater Treatment- Generic (continued)

- **Precipitation (Softening)** – removes hardness by chemical reaction and settling
 - Lime softening
 - Silica removal
 - Heavy metals removal
- **Ion Exchange** – removes unwanted ions by transferring them to solid material
 - Anion exchange (weak base, strong base)
 - Cation exchange (weak acid, strong acid)
 - Regeneration with neutralization
 - Ion specific resins (boron removal)



Wastewater Treatment- Generic (continued)

- **Neutralization** – acid / base addition to adjust pH
 - Neutral pH = 7
 - Neutral pH range = 6 - 9
- **Membrane Separation** – use membranes to remove suspended and dissolved solids
 - Microfiltration (MF) = removes **suspended solids**
 - Ultrafiltration (UF) = removes **suspended solids**
 - Reverse Osmosis (RO) = uses pressure to remove **dissolved solids**
 - Electrodialysis (ED) = uses electricity to remove **dissolved solids**



Wastewater Treatment- Generic (continued)

- **Adsorption** – uses physical adhesion unto porous media to remove unwanted molecules
 - Activated carbon adsorption
 - Resin columns
 - Fluoride removal with alumina
- **Evaporation** – water vaporization / condensation
 - Flow configurations (rising film, falling film, forced circulation)
 - Energy configurations (multiple effect, vapor recompression)
- **Oxidation / Reduction** – uses oxidation / reducing agents to remove unwanted constituents
 - Iron & manganese removal
 - Cyanide removal
 - Sulfide removal



US Environmental Protection Agency Resources

